Diversity of medium-sized and large mammals from Atlantic Forest remnants in southern Minas Gerais state, Brazil

Felipe Santana Machado[1*], **Álvaro Fernando de Almeida**[2], **Dalmo Arantes de Barros**[1], **José Aldo Alves Pereira**[1], **Rossi Allan Silva**[1] and **Alexandre Augusto Spadoni Pereira**[1]

1   Universidade Federal de Lavras, Departamento de Ciências Florestais, Post Office Box 3037, Zip Code 37200-000, Lavras, MG, Brazil
2   Universidade de São Paulo, Campos Salles Street, 1182, Center, Zip Code 13416-310, Piracicaba, SP, Brazil
*   Corresponding author. E-mail: epilefsama@hotmail.com

Abstract: Studies on mammal diversity provide the essential groundwork for the development of conservation methods and practices. The region of the Poços de Caldas Plateau is lacks such studies, which may be a problem for future conservation actions. Here, we analyze the richness of medium-sized and large mammals from Atlantic Forest remnants on the Poços de Caldas Plateau, Minas Gerais state. Diurnal censuses of direct observations and mammal signs were conducted, and we documented 20 species of mammals belonging to eight orders. Three species of primates, one carnivore, one cingulate, one lagomorpha, three rodents, one artiodactyla, and two marsupials were found. The largest forest remnant that presented the greatest richness is currently a conservation unit. Forest remnants are important for the consolidation of management strategies and have fundamental role for the conservation of mammal diversity in the south of Minas Gerais state.

Key words: richness; fauna; Poços de Caldas Plateau; fragmented area

INTRODUCTION

Recently, Paglia et al. (2012) have reviewed the number of Brazilian mammal species and enumerated 701 species belonging to 243 genera in 50 families and 12 orders. Medium-sized and large mammals represent 40.5% of the total. Minas Gerais state has 236 mammal species (Paglia et al. 2009) and approximately 55 species of medium-sized and large mammals, which represents almost 8% of total listed in Paglia et al. (2012). Nevertheless, there are knowledge gaps still exist for the medium-sized and large mammal faunas in several regions in Brazil.

Minas Gerais state has 50 areas of conservation importance according to Drummond et al. (2005). It

is noteworthy that only 6% of these areas are in the southern part of the state. In past years, most published studies on mammals of southern Minas Gerais were on small mammals (Rocha et al. 2011; Mesquita and Passamani 2012; Machado et al. 2013, 2016). There are few publications related to medium-sized and large mammals of southern Minas Gerais state. For example, Eduardo and Passamani (2009) studied the mammal fauna of Santa Rita do Sapucaí, whereas Silva and Passamani (2009), Santos et al. (2016) and Machado et al. (in press) focused on Lavras city and surroundings. The studies mentioned above show the considerable lack of knowledge on the diversity of medium-sized and large mammals in southern state.

The Poços de Caldas Plateau is located in southern Minas Gerais state and is composed of an alkaline massif having a circular shape, which is a unique in the state. This landscape presents a geomorphological formation of the late Cretaceous period (Grohmann et al. 2007). The vegetation of the Plateau is clearly differentiated from the dominant vegetation elsewhere in the state. This vegetation is composed by seasonal semideciduous forest, mixed ombrophilous forest and a significant occurrence of high-montane grasslands (Guimarães et al. 2008).

The vertebrate fauna of this region is rather well known and recent reports have demonstrated a fauna of ecological relevance mainly by the threatened status of many component species. Examples include *Phyllomedusa ayeaye* (B. Lutz, 1966) (Araujo et al. 2007), a treefrog classified by IUCN as Critically Endangered (Caramaschi et al. 2010) and *Rhagomys rufescens* (Thomas, 1886) (Passamani et al. 2011), a sigmodontine rodent classified by IUCN as Near Threatened (Geise et al. 2008). However, there are no studies of medium-sized or large mammals in this region, despite the need for this work in the region (Costa et al. 1998). Therefore, we aim to document and analyze the species richness
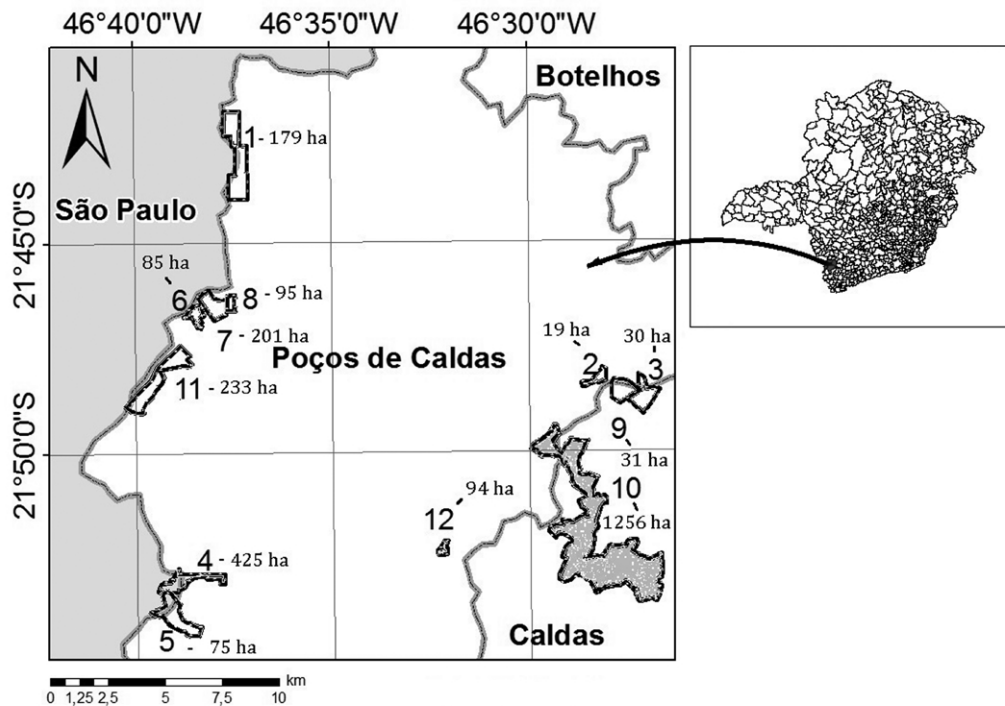
Figure 1. Study area with 12 forest fragments on Poços de Caldas Plateau, southern Minas Gerais state, Brazil.

of medium-sized and large mammals in forest remnants on the Poços de Caldas Plateau, southeastern Brazil, that in turn will lead to increased conservation of this fauna.

MATERIALS AND METHODS

This study was performed on 12 areas distributed in the region of Poços de Caldas Plateau, southeastern Brazil (Figure 1; Table 1). This region has an area of approximately 6,558 km², with elevations ranging between 1,000 and 1,640 m. It includes the main watershed of Paraná River, which is a part of the sub-basin of the Grande River (Cavalcante et al. 1979). On the map (Figure 1), each number represents a remnant of Atlantic Forest. The distances among fragments in the study area are presented in the Appendix.

The climate of the region is classified as Cwb based on the Köppen classification, with a humid climate, dry winters, and temperate summers. The average annual rainfall is 1,482 mm, the annual average temperature is 19.9°C, and the average annual relative humidity is 79% (Alvares et al. 2014).

The vegetation is a mosaic formed by transitional areas of seasonal semideciduous and mixed ombrophilous forests, with significant occurrences of high-montane grasslands (Guimarães et al. 2008), and intensive agrosil-vopastoral activities such as coffee, corn and eucalyptus plantations. This area is an ecotonal region between Cerrado Savanna and Atlantic Forest. Fragment 4 (Figure 1) represents the Reserva Particular do Patrimônio Natural (RPPN) Morro Grande protected area.

Table 1. Study area on Poços de Caldas Plateau with coordinates, fragment size and the surrounding matrix information to south of Minas Gerais state, Brazil. Size of fragments in hectares (ha). The coordinates were obtained at the centroid of the polygon delimiting each fragment.

Area	Coordinates	Size (ha) (distance sampled)	Surrounding Matrix
1	21°43′39.12″ S, 046°37′24.521″ W	179 (14 km)	East side with predominance of eucalyptus plantations and west side with several crops and pasture.
2	21°48′17.08″ S, 046°28′18.719″ W	19 (9 km)	Mostly surrounded by eucalyptus plantations and small areas of pasture.
3	21°48′42.75″ S, 046°27′08.121″ W	30 (9 km)	Surrounded by eucalyptus plantations and small urban areas.
4	21°53′02.36″ S, 046°38′55.043″ W	425 (6.75 km)	Totally surrounded by eucalyptus plantations.
5	21°53′15.77″ S, 046°39′07.716″ W	75 (9 km)	Surrounded by urban areas and small pasture areas.
6	21°46′41.17″ S, 046°38′13.915″ W	85 (13 km)	North and south side with urban areas and east and west side with eucalyptus planta-tions and other forest fragment, respectively.
7	21°46′29.05″ S, 046°38′01.658″ W	201 (15 km)	Surrounded by urban areas and small pasture areas.
8	21°46′26.64″ S, 046°37′33.731″ W	95 (14 km)	Surrounded by rural areas and pasture in majority.
9	21°48′32.55″ S, 046°27′38.234″ W	31 (20 km)	Surrounded by pasture and other forest fragments.
10	21°49′59.61″ S, 046°29′05.653″ W	233 (30 km)	Surrounded by eucalyptus plantations and small urban areas.
11	21°48′14.42″ S, 046°39′27.212″ W	1256 (52 km)	Surrounded by rural areas and pasture in majority.
12	21°52′20.83″ S, 046°32′14.441″ W	94 (10 km)	Surrounded by rural areas and pasture, and forest in recuperation.

Medium-sized and large mammals were surveyed between December 2002 and February 2004 between 06:00 h to 11:30 h and between 15:00 h to 19:00 h when mammal activity is more intense. The "Paths Irregular Method" was used for collecting qualitative and quantitative information through rapid ecological assessments (REA). The procedure is to record the number of individuals of each species that could be accurately identified when slowly moving along the route through the environment.

Pre-existent non-linear transects were walked at a speed of 1 km/h. During the surveys, transects were equally travelled in the edge and inner regions of the fragments. Each area was visited once (fragments 1, 2, 3, 4, 5, 7, 8, 9 and 12) or twice (fragments 6, 10 and 11). However, as some fragments have undifferentiated inner-edge gradients they were reduced in size. Direct observations (animal sightings) and indirect observations (footprints, feces, bones and vocalizations) and the number of individuals (when possible) were recorded. The distances walked in each fragment are presented in Table 1.

We relied on our taxonomic experience of medium-sized and large mammals for identification in the field, as well as following the field guides: Emmons and Feer (1990), Dalponte and Becker (1991), Aurichio (1995), and Oliveira and Cassaro (1997). Scientific names were updated following Paglia et al. (2012) and recent taxonomic reviews were considered in this work, including Trigo et al. (2013) for the *Leopardus tigrinus* (Schreber, 1775) group.

The sufficiency of the sampling effort was evaluated through a rarefaction curve for the total of the sampled area (Gotelli and Colwell 2001) and the first order Jackknife estimator of species richness (Burnham and Overton 1978). The results were obtained using presence and absence data for species in each site sampled. This estimation was generated using 500 randomizations.

RESULTS

Our surveys recorded 30 footprints, 19 direct visualizations, 18 scats, nine vocalizations and one carcass, representing at least 20 species and eight orders (Table 2). The total survey effort was 265.9 hours with a success rate of 0.9 records/hour. Three species of primates, nine carnivores, one cingulate, one lagomorpa, three rodents, one artiodactyle and two marsupials were recorded. We were not able to identify some species recorded via indirect records (e.g., *Didelphis* sp.). No species were recorded in fragments 3 and 9.

The first order Jackknife estimator of species richness predicted a richness of 24.62 species, which was beyond the 95% confidence intervals of the observed cumulative curve (Figure 2).
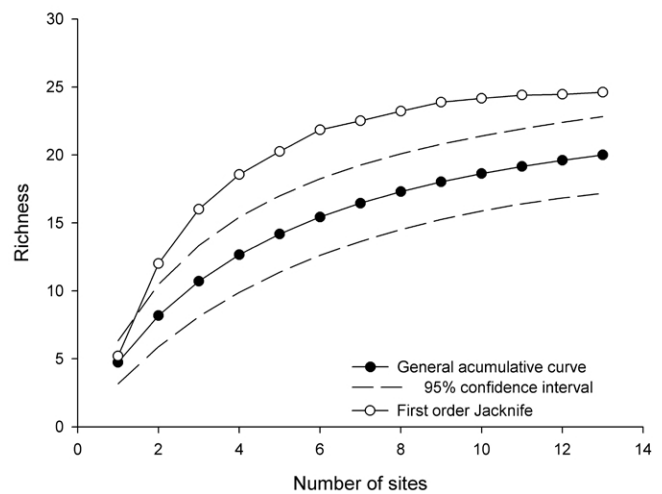

Figure 2. General cumulative curve for the sampled sites and the first order Jackknife estimator of species richness in southern Minas Gerais state, Brazil.

DISCUSSION

From the study area, approximately 82% of the species richness predicted by the Jackknife richness estimator was recorded. This richness can be considered high if compared to similar previous studies: Eduardo and Passamani (2009) found 15 species in the region of Santa Rita do Sapucaí city (MG); Silva and Passamani (2009) found 17 species in forest fragments in the municipality of Lavras; and Negrão and Valladares-Pádua (2006) found 18 species in the Morro Grande Nature Reserve, Cotia (SP). However, these studies differed in methodologies and survey effort from our study, and a direct comparison is difficult. Our use of direct and indirect records, such as footprints and scats, is effective for non-volant mammals, as used previously in the Neotropical region (e.g., Voss and Emmons 1996; Pereira et al. 2001; Silveira et al. 2003; Carmignotto and Aires 2011).

The relatively high species richness that we found is probably related to the large size of some forest patches (fragments 4 and 11 which are 425 ha and 1,256 ha, respectively) in combination with the connectivity between these patches. Large areas may support a higher richness, which is linked to the Biogeography Island Theory of MacArthur and Wilson (1967); in different biomes fragment size influences the observed richness (Bierregaard et al. 1992; Turner and Corlett 1996; Laurance et al. 2011). The potential ranges covered individuals of some species, such as animals of group of the *Leopardus pardalis* Linnaeus, 1758, recorded in this study reach up to 4.5 km (Costa 2007), and the distances between some fragments are less than 2 km (Appendix 1). Thus, there may be some connectivity of these fragments.

Didelphis aurita Wied-Neuwied, 1826, *Callicebus nigrifrons* (Spix, 1823) and *Sapajus nigritus* (Goldfuss, 1809) are restricted to the Atlantic Forest and *Chrysocyon brachyurus*

Table 2. Composition of mammal species recorded in the study areas. The records were divided in "DS"= direct sighting, "T"=tracks, "S"=scats, "V"=vocalizations and "BP"=body parts.

Order Species	Study areas											
	1	2	3	4	5	6	7	8	9	10	11	12
Didelphimorphia												
Didelphis albiventris Lund, 1840	-	-	-	DS	-	-	-	-	-	-	-	-
Didelphis aurita Wied-Neuwied, 1826	-	BP	-	-	-	-	-	-	-	-	-	-
Didelphis sp.	DS	-	-	T	-	-	-	-	-	-	-	-
Cingulata												
Dasypus novemcinctus (Linnaeus, 1758)	-	-	-	T	-	-	-	-	-	-	-	-
Artiodactyla												
Mazama sp.	-	-	-	T	T	-	-	T	-	T	-	-
Primates												
Callicebus nigrifrons (Spix, 1823)	V – DR	DS	-	DS - V	DS - V	-	DS – V	DS – V	-	DS – V	DS – V	V
Callithrix aurita (Geoffroy *in* Humboldt, 1812)	-	-	-	DS	-	-	DS – V	-	-	-	-	-
Sapajus nigritus (Goldfuss, 1809)	-	-	-	DS	DS	-	-	DS	-	-	-	-
Carnivora												
Cerdocyon thous (Linnaeus, 1766)	S	-	-	S – T	S	-	-	S	-	S – T	S – T	-
Chrysocyon brachyurus (Illiger, 1815)	T	-	-	DS	S - T	-	-	S – T	-	DS	-	-
Conepatus semistriatus Boddaert, 1784	-	-	-	T	-	-	-	-	-	T	-	-
Leopardus guttulus (Hensel, 1873)	-	-	-	T	S	-	-	S – T	-	-	-	-
Leopardus sp.	-	-	-	T	-	-	S –T	-	-	-	-	-
Nasua nasua Linnaeus, 1766	-	-	-	T	-	DS	-	-	-	-	-	-
Procyon cancrivorus (Cuvier, 1798)	-	-	-	T	-	-	-	-	-	T	T	-
Puma concolor (Linnaeus, 1771)	S	T	-	S	-	-	S – T	-	-	S	-	S – T
Puma yagouaroundi (Geoffroy, 1803)	-	-	-	-	-	S – T	-	-	-	-	-	-
Lagomorpha												
Sylvilagus brasiliensis (Linnaeus, 1758)	-	-	-	-	-	-	-	-	-	-	DS	-
Rodentia												
Cuniculus paca (Linnaeus, 1766)	-	-	-	T	-	-	-	-	-	T	-	-
Dasyprocta sp.	-	-	-	T	-	-	-	-	-	-	-	-
Hydrochoerus hydrochaeris (Linnaeus, 1766)	-	-	-	-	-	S	-	-	-	-	T	-

Illiger, 1815 is restricted to open areas of Cerrado (Paglia et al. 2012). It is possible that higher richness is more noticeable in the overlap of different environments in this ecotonal region (Costa et al. 2000). However, fragmented and reduced habitats can lose the original community if species are not able to find the resources for long-term survival (Chiarello 1999). Many mammal species are dependent on native vegetation cover. In our study, there are some transitional areas and native vegetation cover. This mixed composition increases the biological importance, which emphasizes the need for conservation of these fragments to preserve their biodiversity.

Most species of medium-sized and large mammals in our study have wide distributions over all of Brazil. However, some species were strongly associated with transitional ecotones between the morphoclimatic domains of the Cerrado and Atlantic Forest, for example, *Chrysocyon brachyurus* and *Callithrix aurita* (E. Geoffroy in Humboldt, 1812) (Chiarello et al. 2008). *Chrysocyon brachyurus* lives mainly in Cerrado areas but can expand their home range because they can occupy open areas with less biomas such as pasture and crops (Corrêa et al. 2000; Chiarello et al. 2008; Rylands et al. 2008).

The order Primates is one of the most endangered groups of mammals (Costa et al. 2005; Chiarello et al. 2008). There are few data on the ecology of *Callithrix aurita*, which is found in Atlantic Forest areas. Although this species lives in small areas of 35.50 ha (with 6 to 11 individuals) (Corrêa et al. 2000), its presence in larger conservation areas (above 300 ha) could be important for its preservation. The western limit of this species' distribution is uncertain (Olmos and Muscatelli 1995), but in Minas Gerais state, it reaches the cities of Itajubá and Pouso Alegre, and its distribution includes the southern part of the state (Rylands et al. 2008). Here, present a small range extension of approximately 60 km for *Callithrix aurita*. Similarly, *Callicebus nigrifrons* is another primate of ecological interest in the study area. This species has broad phenotypic flexibility (São Bernardo and Galletti 2004) and occurs in small forest fragments ranging from 100 to 300 ha, which demonstrates a high capacity to adapt to environmental changes (Trevelin et al. 2007).

Based on geographical distributions, the Poços de Caldas Plateau has a high potential for additional mammalian species not recorded in our study. Inclusion of other survey methods, such as interviews to local residents, might reveal additional species (Voss and Emmons 1996). More studies are necessary, mainly that include groups such as small rodents, marsupials, and bats.

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APPENDIX

Distance between fragments of the study area, south of Minas Gerais, Brazil. The numbers represent the fragments in the study area map and the distance among them in kilometers.

	1	2	3	4	5	6	7	8	9	10	11	12
1	-	16.5	18.8	16.3	17.4	4.9	3.9	2.8	17.4	16.3	6.9	17.2
2	-	-	1.4	16.3	19.5	16.3	15.6	15.1	1.2	4.2	16.7	9.07
3	-	-	-	19.1	21.4	18.4	17.9	17.4	1.2	2.3	18.8	10.2
4	-	-	-	-	0.4	10.2	10.4	10.9	18.4	14.4	6.5	9.1
5	-	-	-	-	-	10.4	10.9	11.2	17.9	13.9	8.1	9.1
6	-	-	-	-	-	-	0.2	0.9	17.4	14.4	1.2	12.8
7	-	-	-	-	-	-	-	0.2	16.9	14.4	1.6	12.8
8	-	-	-	-	-	-	-	-	16.5	13.3	2.6	13.0
9	-	-	-	-	-	-	-	-	-	2.1	17.9	9.5
10	-	-	-	-	-	-	-	-	-	-	14.9	3.0
11	-	-	-	-	-	-	-	-	-	-	-	13.0
12	-	-	-	-	-	-	-	-	-	-	-	-